Report for 2004NY47B: Innovative management of stormwater on under-utilized urban surfaces

- Other Publications:
  - Jawlik, P, 2004, Suspended solid removal from urban stormwater runoff, NSF-REU project report, Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY.

Report Follows

TITLE: Innovative Management of Stormwater on Underutilized Urban Surfaces

Problem and Research Objectives

The 1972 amendments to the Federal Water Pollution Control Act (also known as the Clean Water Act) prohibit the discharge of any pollutant to waters of the United States from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Despite the progress made by these amendments, degraded water bodies still exist. According to the 1996 National Water Quality Inventory, a biennial summary of state surveys of water quality, approximately 40 percent of surveyed U.S. water bodies are still impaired by pollution and do not meet water quality standards. A leading source of this impairment is polluted nonpoint source pollution. In fact, according to the Inventory, 13 percent of impaired rivers, 21 percent of impaired lake acres, and 45 percent of impaired estuaries are affected by nonpoint source urban/suburban stormwater. In New York City wastewater, stormwater, and combined sewer overflows (CSO's) are considered the largest single source of pathogens in the New York Harbor region

The management of stormwater runoff in densely urbanized areas with substantial impermeable surfaces presents a major design challenge. Large volumes of runoff are generated from extensive impermeable surfaces, yet few locations exist within the urban watershed for its storage and treatment using conventional stormwater best management practices (BMP's). The large land areas typically required to construct detention basins, and wet and dry ponds prohibit their use in most urban areas. A further limitation of these conventional BMP approaches is their mixed track record in treating the suite of contaminants (i.e., pathogens, metals, nutrients, DOC, etc.) found in urban stormwater. End of pipe solutions, on the other hand, are costly.

A more viable option for urban stormwater management may be a pollution prevention approach whereby runoff is intercepted high in the urban watershed in or on small, underutilized areas and surfaces before it reaches catchbasins and sewers. These urban stormwater "resisters" can then be used to facilitate evapotranspiration and infiltration vis-à-vis vegetation. Our goal is to design these systems to aesthetically improve the urban experience. This is the biosculpture™ concept developed by the designer, Jackie Brookner. The challenge of using such systems in temperate urban climates is to develop a substrate that is both porous, yet has enough structural integrity to withstand disintegration from freeze/thaw cycles, corrosion, sunlight, pH and other chemical interactions. In addition, the substrate would preferably be made from abundant, locally available materials, and must be economical and sustainable in terms of total life cycle analysis from origin to future uses.

The overall goal of the project is to create prototype structures that function ecologically and hydrologically in a stormwater treatment context, but that also aesthetically enhance urban environments.

Methodology:

Due to a delay in funding arrangements the project started late and is continuing with a no-cost extension. One study that was carried out by Paul Jawlik with the objective to test numerous materials for suspended solid removal ability. The materials were tested for clogging, particulate removal capacity, and hydraulic conductivity with 20 μm particles and where applicable 200 μm particles.

Hydraulic Conductivity Measurement: The materials in Table 1, excluding the volcanic rock, were placed in the base of separate 2.5 inch diameter, open-ended columns. For the rockwool and plastics, silicon glue was applied to the material-column interface to ensure stability and create a watertight seal. For the sand, a mesh of slightly finer size than the sand was placed on the bottom of the column. The Mirafi Geotextile was simply strapped around the bottom of the column. In the case of the whole volcanic rock, expandable foam was applied to the edges so as to make the irregular shape fit snuggly into a 6-inch diameter column. The particulate volcanic rock was placed in a 0.75-inch diameter column with wire mesh attached to the bottom. Water was pumped into the column at a given rate until ponding started. The hydraulic conductivity was then calculated with Darcy's Law.

Table 1: Materials and Properties

Material	Relevant Information
Sand	800-1000 μm Grains
Porex Porous Plastic (Fine)	10-20 μm Pores
Porex Porous Plastic (Medium)	20-30 μm Pores
Porex Porous Plastic (Coarse)	90-130 μm Pores
Grodan Rockwool	Water Flow – Along Grain
Grodan Rockwool	Water Flow – Against Grain
Mirafi Geotextile	1120S
Volcanic Rock	Whole
Volcanic Rock	1000-1500 μm Grains

Clogging: Each material was fitted into a column in the same manner as the samples in the hydraulic test. Approximately 1 gram of 20 μm (mean diameter) Agsco glass microspheres were added to one liter of water. The solution was thoroughly stirred and poured into the test column with the outflow collected. The time for the solution to pass through the material was noted. The concentration of the initial solution and the outflow solution was determined using a Spectronic 501 spectrophotometer. This process was repeated once a day, with the exception of several gaps, for each material until a trend became discernable. For rockwool, an additional test was conducted. One liter of microsphere solution was applied consecutively to the rockwool in one day. A thinner slice of rockwool was also used. Excluding these changes, the same procedures outlined previously were applied.

Larger Particle Filtration: The sand and crushed volcanic rock had void spaces much larger in magnitude than the 20 μm microspheres. These two materials were therefore tested with 200 μm spheres in addition to 20 μm spheres.

Principal Findings and Significance:

Hydraulic Conductivity Phase: Results of the conductivity test are displayed in Table 2. The rockwool had the highest conductivity; water flowed through it quickest. Hydraulic conductivity was dependant on material orientations, with the perpendicular sample having a noticeably higher conductivity. This may be due to non-homogenous qualities of the rockwool. There is going to be a difference in conductivities because the water is not seeing the same both for both orientations. The sand had a slightly lower conductivity than the rockwool and the crushed volcanic rock lower than the sand. The solid volcanic rock was completely impermeable at the time scale considered. The coarse porous plastic, with an average pore size of 90-130 μm, had a hydraulic conductivity five times higher than the medium plastic (20-30 µm) and more than ten times higher than the fine plastic (10-20 µm). .

Table 2: Hydraulic Conductivity Values

Material	Conductivity (m/day)
Mirafi Film	~141
Rock Wool:	
Cut Perpendicular to Grain	596
Cut Parallel to Grain	363
Volcanic Rock - whole	0
Volcanic Rock - crushed	262
Porous Plastic:	
Fine	10.9
Medium	22.6
Coarse	115
Sand:	333

Clogging: The fine and medium plastics removed on the average 10-25% of the 20 µm microspheres while rockwools were able to remove 20-50% on the average depending on the material orientation . The sand, volcanic rock, geotextile, and coarse plastic, however, were poor at removal. The medium and fine plastics displayed very similar behavior. They had high initial removal percentages (up to 90%) followed by steep drop-offs. Also, as their conductivity decreased, they became worse at removing suspended solids. The existence of these similarities is indicative of the plastics' similar pore size relative to each other and to the microspheres. Removing less pollutant as the conductivity decreases is counter-intuitive. The longer water takes to pass through each plastic, the more pollutant the plastic should remove. The plastic having a range of pore sizes, however, creates a range of paths that water can flow through. As solution is added, the smallest paths become clogged while the largest ones do not. Eventually, the solution travels preferentially by wide paths. This not only increases the time for a given amount of solution to pass through the plastic as there is less cross sectional area the water flows through, but it also reduces the solute that can be trapped inside the plastic. The result is a longer passing time with poor removal percentages.

Material orientation was important, especially for the rockwool. The parallel orientation's removal percentage decreased linearly before flattening out with minor oscillations around 10%. The perpendicular orientation on the other hand, displayed different behavior. For the first four days it removed over 50% of the particulates. After its fourth day of being treated, however, the removal percentage changed significantly; large fluctuations in the removal occurred, sometimes with negative removal. This possibly is due to the rockwool having reached a threshold and upon reaching this load, the solids become more susceptible to washing out. This is what appears to be happening from Days 7-11..

The results for the sand, volcanic rock, geotextile, and coarse plastic were all sporadic. Data fluctuated above and below zero removal for all materials except for the sand, which stayed consistently below zero. The materials all have void spaces larger than the microspheres. As a result, they materials do not function well as filters. The coarse plastic, even though it was a poor filtering media, over time restricted water flow.

Larger Particle Filtration: The volcanic rock and sand where efficient at removing the 200 µm microspheres; displaying consistent removal percentages in excess of 80%. There was minor clogging in the sand and major clogging in the volcanic rock. Although the volcanic rock consistently removed around 98% of the micropheres, it also clogged at an exponential rate. The sand was also an excellent filter, removing in excess of 80% in all samples with minor reductions one liter to the next. Although its removal was less than the volcanic rock, it showed no clogging. The high removal percentages and resistance to clogging make the sand a better choice of filtering media for this particle size.

Achievements

The building block for the bio sculptures have been constructed and will be tested starting in July.